WESTERN GOVERNORS' ASSOCIATION

Strategic Assessment of Bioenergy Development in the West

Analyses of Deployment Scenarios and Policy Interactions

FINAL REPORT

Western Governors' Association and Antares Group Inc.
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Strategic Assessment of Bioenergy Development in the West

In February 2008, the Western Governors' Association adopted a policy reaffirming the governors' strong commitment to enhance and diversify the region's transportation fuels portfolio. The *Strategic Assessment of Bioenergy Development in the West* represents a major step in fulfilling that commitment and expands upon earlier work through WGA's Clean and Diversified Energy Initiative and the Transportation Fuels Initiative. The Bioenergy Assessment Team was formed to examine the potential for future development and to create a comprehensive framework to assess environmental, technical and socioeconomic impacts associated with national, state and regional bioenergy and biomass management policies. This assessment will assist the governors individually and collectively as they develop bioenergy policies. The extensive evaluations conducted by the Assessment Team are contained in the following areas:

- Biomass Resources in the Western States
- Biofuel Conversion Technologies
- Spatial Analysis and Supply Curve Development
- Analyses of Deployment Scenarios and Policy Interactions

While the assessment represents the consensus view of its authors, it is not adopted policy and does not represent the views of WGA or any individual Western Governor. Support for this work was provided by the U.S. Department of Agriculture.

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1 Introduction

The analysis team has employed all of the expertise of the Strategic Assessment Team and the Transportation Fuels for the Future[1] Advisory Committee and technical teams to lay out resource and technology development scenarios and the market and policy conditions that could support those scenarios. The date chosen for projecting potential production capability was 2015 so that results would be directly comparable to the Clean and Diversified Energy Initiative (CDEI) analysis for biomass power development in the West. Technology and resources will continue to be developed beyond this near term horizon so that this forecast production capability is not the endpoint but an intermediate point at which Biofuels production could become a significant supply and results can be measured. The scenarios identify what resources, technologies and strategic locations could be developed and the pace at which they might be introduced to achieve the potential for Biofuels production set forth in the accompanying report. ***The expected technology progression and transition from today's technology and processes to tomorrow's vision is provided. The critical transition forecast for this time period is the switch from starch to cellulose resources grown on lands or recovered from waste streams that minimize the impact on standing carbon reserves and food production.*** That is, sustainability is an important criterion throughout our work. In this report we use the term Lignocellulosic Biofuels (LCB) to represent the class of feedstocks and technologies that will enable this transition. In addition to a baseline projection for Biofuels production in 2015, six key sensitivity cases were considered. These variations on the baseline scenario are all valid projections for Bioenergy development and help policy decision makers understand some of the important factors that could increase or reduce Biofuels production capability in the West by 2015.

Scenarios also suggest how the technology transition is likely to proceed while taking advantage of synergies available only in Bioenergy facilities. Meeting the challenge for deploying Biofuels technology at the rates forecast in this strategic assessment will require a private and public partnership of a scope not heretofore applied to Bioenergy development. To better understand what policies would be most effective and efficient to encourage realization of the Bioenergy potential in the West, WGA relied on the expertise of its Advisory Committee on Transportation Fuels for the Future. Under the leadership of the Committee, expert teams on gasoline substitute Biofuels and Biodiesel/Renewable Diesel technologies were formed to advise on the prospects and policy framework that would be required to develop Bioenergy resources for transportation fully. These teams included fuels experts representing stakeholders from industry, government, the environmental community and academia. Their reports received public review and are posted on the WGA website. This work was analogous to the CDEAC Biomass Task force which focused on the use of Bioenergy for Power production.

Using the Governors' goals to frame the policy design, the Advisory Committee reviewed each team's report and produced an overarching policy roadmap, the *Transportation Fuels*

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[1] In 2006, the Western Governors passed the Transportation Fuels for the Future Policy Resolution (http://www.westgov.org/wga/policy/06/futurefuels.pdf) based on their belief that few issues facing the nation are more serious than our reliance on imported oil, the ramifications of global competition for this resource, and the associated risks to our energy, economic, and environmental security. The Governors' launched an initiative to develop a policy roadmap to integrate alternative fuels into a transportation fuels portfolio, taking into account the specific resource attributes of the West. The WGA formed an Advisory Committee comprised of Governors' representatives, transportation experts and stakeholders to lead the initiative.

for the Future: A Roadmap for the West.[2] The policy roadmap and detailed team reports identify what is technically and economically feasible and what is needed to increase the usage of alternative fuels. The objectives of the roadmap are to identify the steps to diversify transportation fuels energy sources, increase the fuel efficiency of the transportation system, and increase domestic production of transportation fuels. An overarching principle is to promote regionally produced clean fuel substitutes to enhance the local, regional, national, and global environment.

These reports served as the basis for the policy resolution adopted by the Western Governors on February 23, 2008: *Transportation Fuels for the West: A Roadmap for Energy Security and Improving the Environment and the Economy*.[3] The Governors' acceptance of the *Transportation Fuels for the Future Report* on February 23, 2008 in a sense concluded the policy formulation phase. It is now up to the states and the region collectively to implement the policy recommendations.

The Transportation Fuels initiative was a collaborative effort designed on the Western Governors' Enlibra Principles[4] that guide their work on complex environmental and natural resource issues.

[2] www.westgov.org/wga/publicat/TransFuels08.pdf
[3] www.westgov.org/wga/policy/08/TransportationFuels.pdf
[4] *Principles for Environmental Management in the West* http://www.westgov.org/wga/policy/05/enlibra.pdf

2 Production Scenario Development

For the CDEAC report the Biomass Task Force considered only electricity as a product from available biomass supplies. In this strategic analysis two biofuel deployment scenarios are examined. The two scenarios are a "2015 Potential Growth" and "2015 Moderate Growth" Biofuels scenarios. 2015 Potential Growth is the mirror image of the CDEAC electricity case for transportation fuels. Using the new technology optimization routine built into the UCD deployment model, UCD generated a supply curve for 2015 that utilizes all of the available resources for fuels production. The model builds Biofuels plants at strategic locations until a target product price is exceeded. Moderate Growth considers a slower build up in lignocellulosic Biofuels capacity that is likely to occur without strong incentives for switching to the feedstock (both to harvest and convert it to fuel) at a large scale and only modest Federal investment in technology improvements beyond the first pilot plants.

A target maximum price for Biofuels is set that corresponds to the Target Product Price (TPP) established for the CDEAC electricity case. The value for the CDEAC analysis was established as a cutoff for the wholesale price of power that was considered a reasonable price to pay for renewable bulk power in 2015. The CDEAC pegged the maximum target price for renewable power in the West at $80/MWh. The WGA analysis team determined that this would be a 38% premium above the average wholesale price of conventional power in the Western States in 2015. The price escalation is based on EIA data on the baseline energy prices (December 2006) and the AEO 2008 reference case forecast for future power price escalation in the West to 2015.[5] The AEO 2008 forecast projects 2% de-escalation in retail electric prices between 2006 and 2015. We assumed that wholesale prices would escalate at the same rate as retail prices on average, primarily because fuel/feedstock costs are the primary driver of energy price escalation.

2.1 Scenario 1: Forecast for Biofuels Development without Competition from Biopower

On parity with the CDEAC assessment for Biopower, the target prices for Biofuels delivered to the terminals in the Western States by 2015 were set at $2.40/gge for gasoline replacement and $2.36/gge for diesel replacement.[6] At that price the model predicts a potential Biofuels production capacity of 7.6 Billion Gallons per Year (gasoline equivalent) **Error! Reference source not found.** provides the forecast production mix in the West for the leading Biofuel contenders. For comparison, EIA projects the wholesale price of ethanol in 2015 will be $1.71/gallon ($2.61/gge).

[5] AEO 2008 Reference Case Table A8 Electricity Supply, Disposition, Prices, and Emissions

[6] Equivalent to $20.71/MMBtu for gasoline replacement ($1.58/gallon of ethanol) and $20.29/MMBtu for diesel replacement fuels ($2.43/gallon of Biodiesel) paid at the terminals for distribution.

Table 1- WGA Forecast for Biofuels Production Potential by 2015

Technology	Output Fuel (MGY) Volume	Product	GE	Technology Category Current	Emerging
Dry Mill Ethanol	3,996	Ethanol	2625.4	2625.4	
Wet Mill Ethanol	335	Ethanol	220.1	220.1	
LC Ethanol	6,716	Ethanol	4412.4		4412.4
LC Middle Distilates	0	Diesel			
FAME "Biodiesel"	0	Biodiesel			
FAHC "Renewable Diesel"	276	Diesel	305.3		305.3
LC Gasoline	0	Gasoline			
Total	**11,323**		**7,563**	**2,845**	**4,718**
Note GE = Gasoline Equivalent based on LHV per gallon of fuel				38%	62%

All of the scenarios begin in 2007 with an established production capacity in the Western US of 2980 MGY ethanol and 170 MGY Biodiesel using current production methods and feedstocks - corn and oil seed/animal fat respectively.[7] The forecast growth in production capability between 2006 and 2015 is illustrated in **Error! Reference source not found.**. Both "Potential Growth" and "Moderate Growth" cases are evaluated.

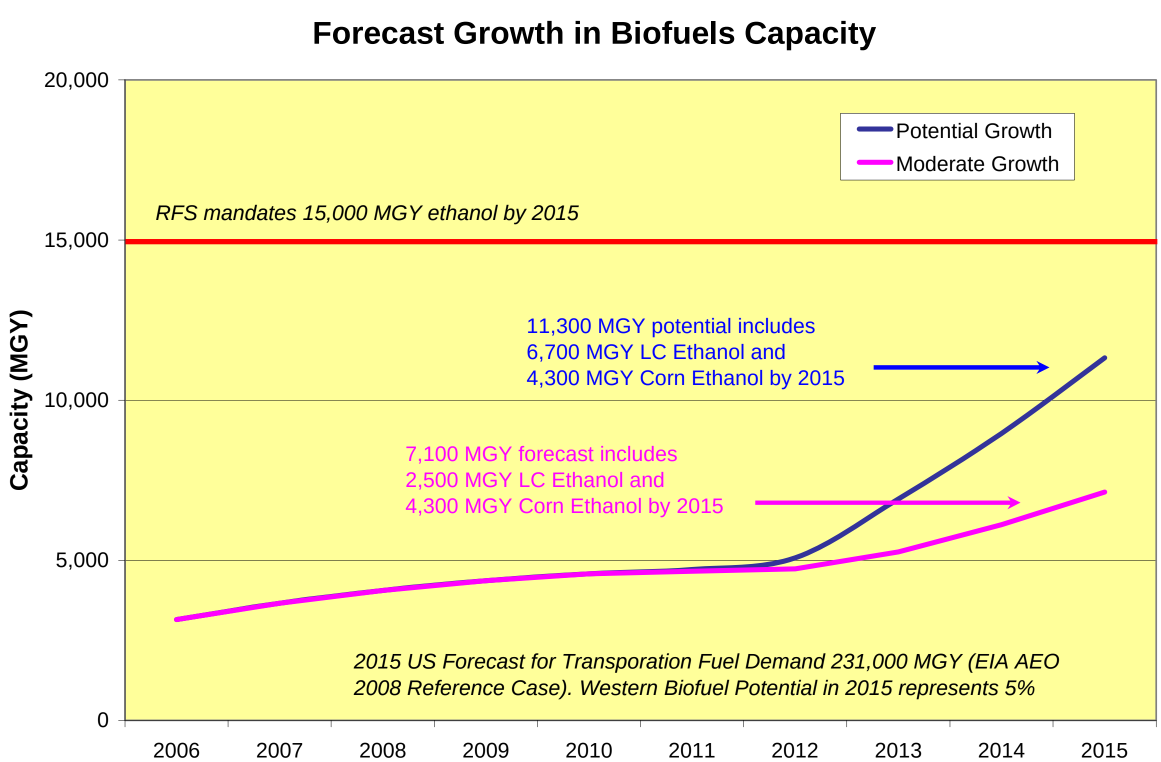

Figure 1 - Forecast Growth in Biofuels Capacity

[7] While corn based ethanol production is forecast to continue to rise and eventually plateau the analysis team did not use the same degree of precision in forecasting the continued operation of FAME facilities. In reality many of these facilities will continue to operate although with price pressure on feedstocks from then new technology FAHC. More importantly the team forecasts greater production of diesel substitutes in 2015 and a switch from soy to waste fatty acid resources.

By 2015 the WGA projected mix of Biofuel production processes shifts to ethanol from lignocellulosic feedstocks and diesel from hydrotreatment of fatty acid feedstocks. The former is an extremely important shift in feedstock choices. Lignocellulosic feedstocks can be produced from a variety of sources without impacting food production capacity. Land use and harvesting constraints are necessary to assure that aspects of sustainability are met and they do limit the potential of this feedstock for fuel production.[8] However within these constraints Herbaceous Energy Crops (HEC) now in trial or demonstration plots throughout the U.S. are expected to provide a key source of lignocellulosic feedstocks in this forecast expanding the ample resource base of forest, crop and urban residues by a factor of two.

The following essential points should be kept in mind when interpreting the results of the strategic analysis:

- The specific mix of production technologies will change as new Bioenergy technologies described in this report achieve cost targets below the expectations described in the technology section increasing their potential for market share in production.
- Alternatively some technologies will experience setbacks in development delaying their impact.
- The Potential Growth trend line represents a four-fold increase in Biofuels representing the amount of production capacity that could be online and meet the target price by 2015 if the representative technologies meet their development goals in the next few years and achieve widespread commercial acceptance.
- The Moderate Growth trend line represents a slower likely build up of production due largely to the slower rate of injection of investment in technologies that are just entering the commercial market with a very limited track record and only modest government support.

Achieving either the potential growth or realistic growth forecast for Biofuels production is dependent on the following critical assumptions:

- A combination of government incentives and standards will be in place by 2010 to close the projected gap in pricing between the target price[9] for Biofuels and the DOE forecast prices for conventional fuels in 2015 while assuring the sustainability of the resource. Alternatively, conversion technology and feedstock production innovations that exceed the Biofuels cost and performance projections will also reduce the gap. Conventional fuel price trajectories above DOE forecasts[10] used in this report will have a similar impact on Biofuels competitive position.
- Biomass feedstocks must be established, harvested and delivered at the prices projected in this study and described in Chapter 1. This target is readily achievable but advances in yields and harvesting technology while managing sustainability are needed to enhance the competitive position of Biofuels and encourage rapid deployment. Ramping up the production of energy crops component of supply at the projected pace will be especially difficult to achieve.

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[8] Specific examples of boundary conditions imposed on resources in this assessment include: limiting the production of native grass feedstocks to marginal farm and rangeland without the use of irrigation.
[9] The CDEAC pegged the maximum target price for renewable power in the West at $80/MWh. This equates to a 38% premium above the average wholesale price of conventional power in the Western States in 2015. The same ratio was applied to the wholesale price for Biofuels.
[10] From 2007 to 2008 EIA increased it's forecast price for retail gasoline in 2015 by 15% (Annual Energy Outlook reference case).

- Public acceptance of large scale Bioenergy production rests upon governments providing the necessary safeguards to ensure sustainable production and harvest as much as it depends on regulating the environmental impacts of Biofuel production plants.
- Biofuel Conversion Technologies represented in this report need to meet or exceed their cost and performance targets as described in Section 2. Furthermore, to ramp up production by 2015 they must demonstrate that they can achieve the projections[11] by 2010 and are ready to build at full scale by 2012.

2.2 Comparing Potential Growth and Moderate Growth

Biorefineries using new technologies have only a four year window to achieve the potential deployment determined in this analysis for 2015. This is by far the most difficult technical challenge for meeting the potential supply targets. It means that as the technology is being proven potential new sites and investors are being lined up at the projected pace. Even then the time frame is extremely short. The “Moderate Growth” forecast takes these factors into consideration and represents a case where private and government investment in the technologies remains at current levels. In a like manner, the biomass feedstock resource must be developed at a comparably rapid rate. The assessment team believes that if the other targets are met, this can occur at the pace projected. The most serious policy hurdle to this rapid development will be questions surrounding sustainability of the resource and ensuring ecologically sound establishment and harvest methods. There are frameworks in place to support this process but failures in this arena and any resulting negative public reactions will slow development down.

Error! Reference source not found. provides key statistics for the potential growth trajectory for deployment of lignocellulosic ethanol production facilities on one of many possible trajectories toward the forecast production potential.

Table 2 - Key Deployment Metrics for the Biofuels – Potential Growth Scenario

Metrics - Cumulative	Units	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Facilites Capacity	MGY	3,150	3,660	4,060	4,360	4,581	4,711	5,081	6,916	8,961	11,323
Dry/Wet mill	MGY	2,980	3,480	3,880	4,180	4,331	4,331	4,331	4,331	4,331	4,331
LCE	MGY	0	0	0	0	70	170	570	2,370	4,370	6,716
FAME	MGY	170	180	180	180	180	160	130	90	50	0
FAHC	MGY	0	0	0	0	0	50	50	125	210	276
Feedstock	*(dry tons)*										
Corn	1,000 Tons	23,482	27,422	30,573	32,937	34,127	34,127	34,127	34,127	34,127	34,127
	1,000 Acres	*6,617*	*7,535*	*8,282*	*8,798*	*8,996*	*8,868*	*8,749*	*8,633*	*8,520*	*8,405*
Forest LC resources	1,000 Tons	0	0	0	0	116	283	948	3,941	7,267	11,168
	1,000 Acres	*0*	*0*	*0*	*0*	*9*	*22*	*75*	*310*	*572*	*879*
Agriculture LC residue	1,000 Tons	0	0	0	0	122	295	990	4,117	7,591	11,666
	1,000 Acres	*0*	*0*	*0*	*0*	*69*	*169*	*566*	*2,353*	*4,338*	*6,667*
HEC LC resources	1,000 Tons	0	0	0	0	449	1,090	3,654	15,193	28,015	43,055
	1,000 Acres	*0*	*0*	*0*	*0*	*150*	*363*	*1,218*	*5,064*	*9,338*	*14,352*
Urban LC Resources	1,000 Tons	0	0	0	0	198	482	1,615	6,716	12,384	19,032
Seed Oils	1,000 Tons	639	662	627	593	418	279	151	52	0	0
Waste Grease	1,000 Tons	14	22	43	54	145	161	157	163	171	198
Tallow	1,000 Tons	6	14	27	51	135	376	391	625	850	907

[11] All the new generation technology plants scheduled for commissioning by 2010 will be pilot plants. Demonstrating achievement of the goals means that results at the pilot scale indicate that the cost/performance targets will be met at commercial scale allowing for scale-up and application of lessons learned at the pilot scale.

The conversion of lignocellulosic biomass to ethanol via enzymatic hydrolysis and fermentation is currently a good representative of the first step beyond starch based technology for ethanol production. For that reason and other characteristics of lignocellulosic feedstocks it can also avoid or minimize the impact on food production. Lignocellulosic feedstocks are currently produced from woody biomass from forested land that is not in agricultural production and from the byproducts of food production so that both food and fuel are produced simultaneously. In the near future energy crops can add to the feedstock supply. The impacts on food production can be minimized even when the crop is a dedicated energy crop to the extent that best management practices are adopted and the crop is grown on “marginal cropland” that is less suitable for high yield food crop production typical in the U.S. For example lands with this designation in native grass mixtures can be harvested without foregoing benefits of soil conservation given constraints on certain land base climatic and physical attributes. Clearly if the value of energy outstrips food products then only regulation will inhibit the conversion of prime irrigated farmland.

The overall endpoint for the production levels by 2015 is determined by the analytical methods described in this report. However the temporal distribution of the plant additions is based on the best judgement of the analysis team. Early demonstration for LCE technologies beginning in 2010 is critical to the entry of these technologies and the associated feedstocks in time to have an impact on Biofuel production by 2015.

Feedstock choices are critical to the future of Biofuels production. While corn is the predominant resource today and we have projected on an economic basis that production in the West could double the analysis team is forecasting that lignocellulosic feedstocks would be the predominant feedstock choice by 2015. This projected switch in feedstock choices (symbolically from the corn kernel to the stalk) is considered crucial to the long-term sustainability of the technology.

indicates the rapid ramp-up of herbaceous energy crops needed to meet the forecast potential Biofuels production by 2015.

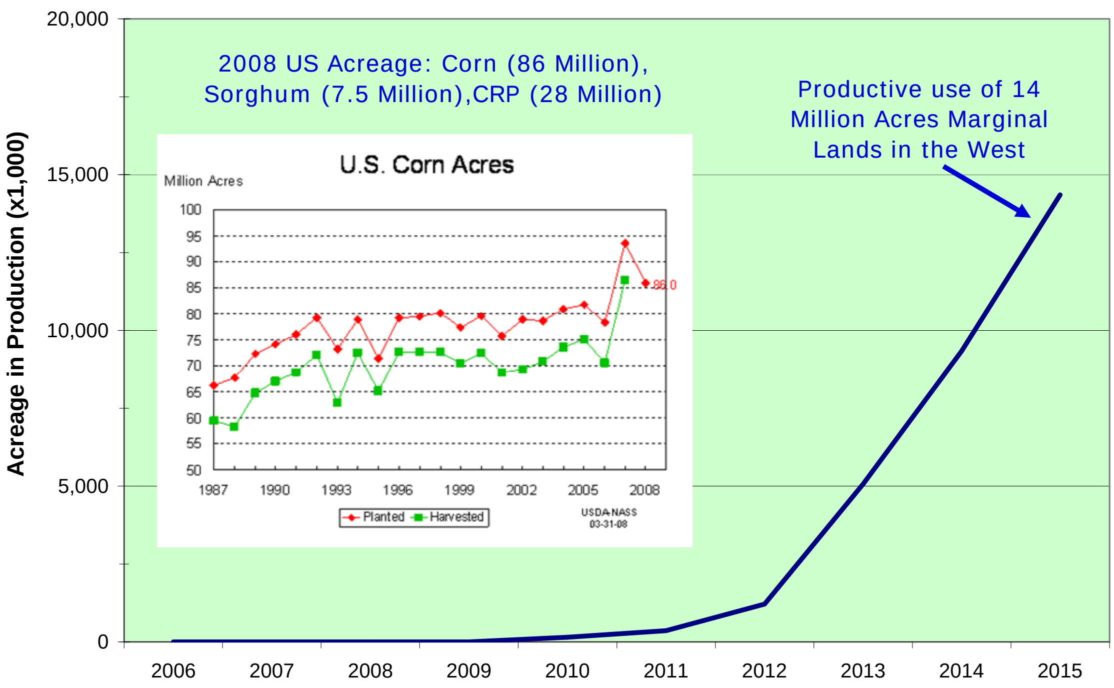

Figure 2 - HEC Land Development Forecast

The challenge of establishing this acreage is every bit as daunting as developing the corresponding Biorefinery capacity in the "Potential Growth" scenario. All of the land necessary to meet this level of HEC planting was selected from suitable acreage available in the West. A key limitation that the analysis placed on HEC feedstocks is that the resources would only be developed on non-irrigated land and subject to select sustainability criteria concerning climate and field-level physical attributes. **It is a self imposed limitation for both practical reasons and for policy reasons – energy feedstocks should not significantly impact acreage for food production.** It is possible that future land use policies at the state or federal level could discourage the use of certain crops (but not the crop residues) for Biofuels production. However it is more likely that with appropriate regulation of the types of land designated for Biofuels crops, energy production would not threaten food production.

2.3 Variations on the Baseline Resource Projections

Six sensitivity analyses were performed; four resource sensitivities and two technology sensitivities. The analysis team believes that all of these alternative scenarios have validity, under the circumstances described for each below. These alternative scenarios help drive home the conditions under which Bioenergy production could be accelerated or constrained depending on policy and technology research and demonstration successes or setbacks. An overview of the analyses and results is given below. A more detailed discussion of each sensitivity case is provided in Chapter 3.

2.3.1 Increased Forest and Herbaceous Energy Crop Yields

There is large uncertainty associated with the resource assessments for forest resources and for native grass energy crops. The rise in interest in alternative fuels has sparked significant private and federal investment in the development of Herbaceous Energy Crops (HEC) to provide an expanded resource for lignocellulosic ethanol production. Yields in highly managed and irrigated experimental test fields have approached 10 tons per acre per year dry biomass feedstock. The analysis team found sufficient scientific evidence to feel comfortable projecting a yield increase 50% greater than the baseline case under Western climate conditions and light field management practices by 2015 (Cassida 2005, Hooper 1999, Schmer 2009). The results indicate a potential increase in Biofuel production in the West of 15% compared to the baseline at the target price. This increase is indicative of the potential for greater production if higher yields and better management practices are achievable. The interesting result is that although LCE Biofuels production increases by 20% the amount of land in HEC plantings decreases by 10% due to more efficient use of the land base for feedstock production. This efficiency has important implications for sustainability and farm profitability.

There were also two forest resource assessments performed by Ken Skog et al., of the Forest Service, to capture the uncertainty in forest-based biomass supply. In addition to the baseline, a "high forest" case assessment was performed. The result of switching to a "high forest" case in the integrated supply curve is an increase of 850 million gge per year in Biofuel production at the $2.40/gge, and an even greater increase of 1,500 million gge per year at $3.00/gge.

2.3.2 Corn Commodity Price Variations

One limitation of this analysis is the treatment of corn supply as available at a single projected commodity price. The baseline case uses a price of $3.05 per bushel from the FAPRI projections for supply and price for 2015. The single commodity price causes corn ethanol to have a very flat supply curve. We performed three sensitivities of corn price by increasing or decreasing the price by 50 cents per bushel, and another increasing the price by $2.00. We found that lower corn prices would have a large impact on the quantity of biofuel available at the target price, increasing production to 11 billion gge per year. Higher corn prices eliminated the fuel produced from corn at the target price.

2.3.3 Limitations to Crop Production for Biofuels

Recent articles have called into question greenhouse gas emission benefits attributed to Biofuels produced from crops (corn, seed oils and herbaceous energy crops) due to induced land use changes, including indirect impacts. If these findings prove to be valid for the crops grown in the WGA region, the Biofuel industry could have a significantly smaller resource base to work with. The impact of removing corn, seed oils and herbaceous energy crops from consideration results in a 66% reduction in Biofuels production.

2.3.4 Slower Technology Development

The development of a Biofuel technology that meets the projected performance of lignocellulosic ethanol technologies in this analysis is important to achieving the supply at prices shown in the results. To bound the impact of this technology improvement, we have performed a scenario of stalled technology where the lignocellulosic ethanol technology only achieves the near-term performance described in the Task 2 report. This includes significantly higher conversion costs and lower yields. At this lower level of performance the supply of Biofuels is significantly reduced at the target price (22% of baseline). From another perspective, it will take $0.28 per gge more to induce the same quantity of fuel production at the same technology status. This represents a shift from lignocellulosic resource use to a larger reliance on corn-based ethanol.

2.3.5 Scaling Up Biorefinery Production Plants

By building larger Biorefineries, the fixed costs can be spread over a larger quantity of fuel produced. In this analysis, we account for these economies of scale but we place a cap on the size of the Biorefinery. It is uncertain at this time what the maximum size of these facilities will be. We analyzed the sensitivity by increasing the maximum capacity of the LCE Biorefineries from 100 MGY to 200 MGY while holding the unit cost of conversion constant beyond 100 MGY. This resulted in only a small cost savings at the low end of the supply curve, which resulted in an increase of about 8 million gge in biofuels production at the target price. This occurs by improving the economics of Biofuel production in areas with very high density resource bases.

2.4 Facility Design and Siting Trends

For all scenarios, waste minimization is an essential design objective for the Biorefinery. Maximum use of all the resource delivered to the Biorefinery gate is important to both economics and sustainability. In contrast to petroleum refineries, the Biorefineries are not

only producing renewable fuels for transportation; they are using renewable resources to provide power and process heat to the plant further reducing the dependence on nonrenewable energy.[12] This is a similar effect to using Biodiesel for farm and forest harvest and transport equipment in the feedstock production and delivery portion of the system.

Reviewing the spatial distribution of Biorefineries forecast by the model, the most active areas of development will be the states bordering the Great Plains and the Pacific Coast. The combination of soils, weather and existing agriculture give these states an advantage in the deployment scenarios.

While the analysis looks toward future Biofuel production in this work, the more than 125 existing corn ethanol facilities in the Western Region represent a significant investment and ongoing production capability. To capture the financial advantages of these facilities, the analysis evaluated their conversion costs in the future supply mix. The capital costs for each existing facility are discounted based on the age of the facility resulting in reduced conversion costs. The existing facilities are then modeled in the optimization with two potential outcomes. They either operate at full capacity if profitable or they close and are replaced by newer technologies.

2.5 Multiple Bioenergy Products: Biofuels, Power and CHP

A third important scenario is the multi-product scenario wherein heat, power and fuels all use a share of the resource in proportion to established economic criteria for each component. The analysis team did not propose to perform detailed energy market simulation modeling but agreed to indicate which resources and technologies are likely to provide more competitive products at intermediate points along the supply curve for 2015.

Biomass can play a dual role in the nation's ability to meet transportation energy needs without increasing GHG emissions. Biofuels will play an important role in supplying the nation's liquid fuels and can contribute to the continued diversification of fuels for power production. To the extent that electricity increases its share in providing energy for transportation service via a transition to "plug in hybrid" and other electric drive vehicles, Biopower can serve the transportation sector through power production. In the modeling efforts cited in this report most lignocellulosic Biofuel conversion facilities produce power and steam from energy rich byproducts to meet on site demand. In some cases there is excess generation that can be supplied to the grid. Thermochemical conversion routes for biomass offer the special flexibility of allowing plants to produce both Biofuels and Biopower each as a primary product. That flexibility could provide an important market edge in the future.

Unless public policy drives the resource predominantly to one product, there will be active competition between Biopower and Biofuel project developers. There are signs of that competition already as the pilot lignocellulosic Biofuel plants are being developed and come on line while utilities and independent power developers are taking advantage of RPS incentives for renewable power. The winners in this competition will be the projects that can extract the most value from the resource and can afford to compete for the available biomass feedstocks. The WGA CDEAC and Biofuels Strategic Assessment results for the year

[12] A similar trend is evident at petroleum refineries where increasing amounts of byproducts are being gasified to fuel combined cycle power resources on site. Pulp and paper facilities have for many years self generated power and steam from waste wood. In the petroleum case the byproducts are not renewable.

2015 provide an interesting view of the potential competition for lignocellulosic feedstocks, as shown in Error! Reference source not found..

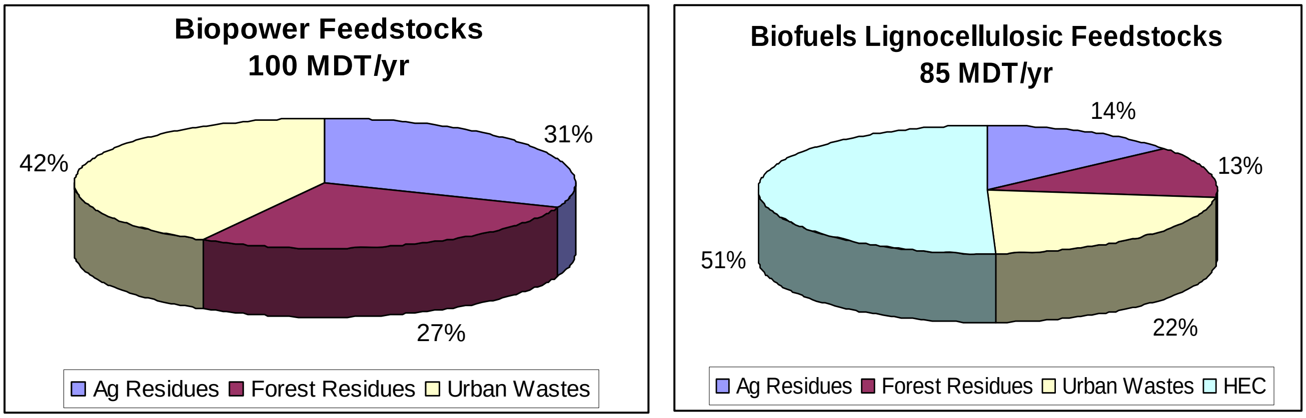

Figure 3 - Comparison of Power and Fuels Feedstock Sources

The Biofuels Assessment included HEC resources which are forecast to be a key component of the supply for Biofuels. The Biopower assessment at the outset concluded that energy crops would not be a key supply for power projects based on project fuel prices. This implies that the HEC portion of the supply would be largely dedicated to fuels production with little competition from power projects. This assumption is analogous to the assumption that seed oils, tallow and greases would be directed toward Biodiesel production rather than power based on feedstock costs. Whether these assumptions will hold up in the future is open to debate. Clearly the greatest area of competition for lignocellulosic resources will be in the forest residues, agricultural residues and urban biomass categories. As a simple first order approximation of the competitive differences between power and fuels productions Antares used its model that predicts competition among Bioenergy projects with different characteristics, sizes and locations. For this case (location and actual plant size is generalized) we applied our projected facility costs and performance for power and fuels to provide a sense of the ability of those projects to compete for supply on the basis of price.

Power projects have long benefited from the ability to convert many types of fuels to power. This has helped provide diversity in generation which helps to moderate electricity price swings and fuel costs. As more resources are drawn upon to supply energy to the transportation market, that sector will benefit from a diversity of resources. However that change will take time and for the 2015 time frame pressure in the transportation fuels market will tend to make Biofuel production the premium energy product if the new technologies succeed. For this evaluation Antares incorporated the capital costs and performance characteristics of both WGA led Bioenergy assessments and included Antares in-house model for a biomass repowering case.[13] The product prices at the wholesale level were assumed to be the targets used in each report – $80/MWh electricity and $2.40/GGE gasoline substitutes.

The results suggest that under the technology and energy price forecasts used in these assessments, Biofuels producers will generally have a competitive edge in feedstock acquisition, **Error! Reference source not found.**. Many factors will influence this relative ability to compete for feedstocks. One clear factor is plant scale. A plant consuming twice as much biomass as its competitor in the same supply shed will have to cover additional

[13] The Project entailed the repowering of a 160 MW coal fired boiler for a major utility in the Southeast. Project development was publicly announced in May of 2008.

transportation costs to reach supplies further on the periphery (c.f. IGCC and LCE examples below). Another factor that may be an important influence in this time frame is the ability to use existing infrastructure and distribution channels to reduce the initial investment risk. Power generation facilities that can be repowered with biomass and ethanol facilities or refineries that can expand production with lignocellulosic feedstocks could have a competitive edge over the establishment of greenfield facilities. Some of the DOE demonstration plants are adding a lignocellulosic feedstock processing facility at an existing corn ethanol facility to expand production capability. It is also possible with substantial investment that lignocellulosic feedstocks could be substituted for starch feedstocks at an operating ethanol plant with major modifications to the existing facility while preserving much of the infrastructure. This case we were not able to evaluate under the current scope of the project but could achieve the same order of capital cost reductions that a biomass repowering project enjoys.

Table 3 - Estimated Feedstock Affordability by Technology

Technology	Capacity	Feedstock Input (Green ton/yr)	Max Affordable Avg. Cost ($/Green ton)
Lignocellulosic Ethanol (LCE)	100 MGY	2,116,600	47
Greenfield Biopower – Steam Turbine	100 MW	943,600	26
Greenfield Biopower – IGCC	100 MW	581,900	43
Repowered Biopower	100 MW	995,500	41

Notes:

- Yields and feedstock input requirements for all facilities based on hardwood (i.e. poplar).
- Target price for ethanol is $2.40/gge. The total installed cost for the LCE facility includes estimated cost for under a mile rail spur or barge unloading facility. The ethanol also includes transportation cost (average distance of 20 miles for each gallon of fuel transported, based on rail transport metrics).
- Target price for power is $0.08/kWh. The total installed cost for the Greenfield biopower facilities includes substation cost plus under a mile for interconnection. No interconnection or substation costs are added to the repowered biopower facility.

3 Policy Recommendations Supporting the Deployment Scenarios

3.1 Barriers and Challenges to Biofuels Development in the West

The Western region has significant biofuels potential. However, there are challenges to reaching this potential. Some of these challenges are unique to the West such as scarcity of water and agricultural conditions. Other challenges apply broadly such as the need for technology breakthroughs for advanced biofuels, including cellulosic ethanol. The major challenges to biofuels development are discussed below.

Technology

Producing alternatives to starch-based ethanol such as LCE and biobutanol offers potential by using agricultural and forestry residues and dedicated energy crops thus reducing the potential food impacts we now see from our use of corn as the primary ethanol feedstock. However, the technology to produce LCE and biobutanol has not been demonstrated at commercial scale. Likewise, feedstocks such as municipal solid wastes are abundant but we have limited technological experience at commercial scale.

Biodiesel technology is well understood and commercially viable today. Renewable diesel, which is being demonstrated in Europe, is just beginning to be developed in the U.S.

Feedstock

The West has broad expanses of land that could be used for producing biofuel feedstocks including potential cropland, forests and waste. However, much of the West is unsuitable for growing irrigated crops because of climate, soil and water.

Soybean oil has been the dominant biodiesel feedstock in the U.S. However, soybeans are only produced in approximately six states of the WGA region, and soybean oil will not be able to provide the feedstock base necessary to meet the growing demand for biodiesel/ renewable diesel in the distillate fuel market. Other potential oilseed crops include sunflowers, canola, cotton and peanuts. Future choice of feedstocks will be a function of many factors including:

- Competition for acreage from other crops and for oil in other markets,
- Availability of crush or ginning facilities within economical transportation distances, and
- Market demand.

While the technology to produce starch-based ethanol is well demonstrated, producing more than 12-15 billion gallons a year would require an unacceptable use of cropland by causing major crop shifts, impacting land committed to wildlife values, causing significant price increases, and possibly impacting food supply within this country and on a global scale.

However, there is huge potential for lignocellulosic feedstocks using agricultural and forestry residues. The challenge in using agricultural residue is determining the amount of residue that can be removed to ensure sustainability in the future. Sustainability is also an issue for forest residue use. Access to forest residues is an additional challenge due to terrain and

public sentiment. Dedicated energy crops such as perennial grasses are a potential new biofuel feedstock source. To be viable however, research is needed to determine growing conditions including soil, climate and water requirements.

Both forestry and agricultural residue harvesting and treatment will require new and different equipment. Research into the equipment is needed, followed by commercial development. Investments by producers may be significant. Likewise, new cellulosic feedstock storage requires development of methods and mechanisms to meet the diverse conditions in the West.

Production and Infrastructure

Key barriers for biodiesel and renewable diesel production include economics of the production process and uncertainty of the market. The economics are tight when the feedstock price is high. Market uncertainty factors include price elasticity for public consumption, product quality assurance, uniform labeling, and the need for public education.

Large-scale cellulosic conversion systems will require large scale feedstock collection, handling, transport and delivery as well as potentially new technology. Technology needs to be developed and then acquired by producers. Additional work is needed in densification and pre-processing techniques and technologies. The transportation infrastructure that will be needed to move large quantities of feedstock to biorefineries will be significant, whether by road or rail. Truck transport can have major impacts on existing road systems with resulting impacts to communities. Again, public and private investment will be a challenge.

Financing/Economics

The established technologies used for starch-based ethanol and biodiesel have been able to attract sufficient financing to become economically viable. For new technology development, financing continues to be a challenge. The Department of Energy (DOE) contracts for large- and mid-scale lignocellulosic facilities will help determine commercially appropriate technologies, but financing the early commercial plants may be difficult.

Regulatory

Regulating new industries and products can be a challenge, particularly finding the balance between consumer protections and facilitating burgeoning development.

Life-cycle Environmental Impacts

Environmental and societal impacts are becoming major issues in a future biofuels economy. Referring back to the goals above, we are seeking to produce alternatives to petroleum products while concurrently addressing environmental issues including greenhouse gas and air pollutants, limited water, and land use. Uncertainties about these environmental impacts are likely to become larger issues until they are better understood by decision-makers and the public. These uncertainties include greenhouse gas and water impacts of producing feedstocks and conversion systems and also greenhouse gas and other environmental impacts of changing land-use, including converting land to new feedstock production and changing agriculture from food to biofuel feedstocks. These are the direct land-use impacts. Extensive indirect land-use impacts are beginning to be identified.

3.2 Policy Recommendations

The Governors can agree on the goal to integrate alternative fuels into a transportation fuel portfolio, taking into account the specific resource attributes of the West. However, each of the Western states has differing environmental, economic, and societal issues that make adopting regional policies challenging. Each of the states has different resource potential for alternative fuels. And finally, each state has a different political environment that influences the scope of policy actions as well as their timing.

It is increasingly clear that decisive leadership is needed at the federal and state levels to expand production in ways that deliver biofuels to consumers at lower prices, more efficiently and in greater quantities. The following recommendations are a set of state, regional, and federal policies that would work together to meet the aggressive goals under consideration.

The necessary policy framework to take biofuels from an important but modest blend component of gasoline to a fuel source that replaces substantial quantities of transportation fuel produced in all regions of the nation would require the following actions:

- Sustained expansion and improved alignment of research, demonstration and technology transfer efforts in the federal, state, and private spheres;
- Innovations and support for cellulosic ethanol and other biofuel feedstock supply;
- Steady increases in the demand floor for biofuels commensurate with the numbers of compatible vehicles; and
- Innovative approaches to catalyzing the development of infrastructure for higher blend ethanol fuels and other biofuels.

While wanting to expand alternative fuels, the Governors are concerned over how transportation fuel choices affect air quality, contribute to global warming and stress our water resources. Specifically, how do we minimize adverse environmental impacts? How do we track the numerous unintended consequences as we deploy new technologies and reallocate our resources?

To answer these questions, it is recommended that the Governors promote tools to evaluate and monitor new alternative fuel technologies for the impact on the environment. Specific recommendations are:

- ❑ Adopt a common life cycle analytic methodology and modeling structure to evaluate greenhouse gas emissions and land, air and water impacts. Regionally cooperate on a single, widely accepted set of assumptions and methods to improve cost-effectiveness of monitoring and facilitate trading of credits among states, if and when a carbon credit trading system is established.
- ❑ Implement a regional framework for cooperation on the development of a performance-based greenhouse gas standard for transportation fuels.

The following is a list of policy elements that can help achieve the Governors' goals. Of utmost importance is an integrated strategy that ties these elements together in a coordinated fashion and considers the importance of collaboration across state and federal efforts.

3.2.1 Research, Demonstration and Technology Transfer

Technological breakthroughs and incremental process improvements are the bedrock of expanding production of ethanol and biofuels and, in particular, delivering the promise of cellulosic ethanol. Ensuring that we expedite delivery of needed technological breakthroughs requires vastly improving the coordination of federal resources and efforts with private and state efforts. The following are recommendations to help achieve the needed breakthroughs and improvements.

National

- Advocate for full funding of DOE's biomass research and demonstration activities, including its genomic work aimed at achieving dramatic changes in how ethanol and other biofuels are produced. Algae production could potentially enhance the biodiesel industry. However, funding and research facilities are needed to reach the potential.
- Advocate for full funding of the Department of Agriculture's (USDA) biomass research and development program at its authorized level. Funding to allow this program's complementary focus on feedstock collection and other agricultural issues is essential, or it will become a weak link in the national effort to move toward cellulosic-derived fuels and other biofuels. Substantially greater leadership and resources are needed so the USDA's unique expertise in the areas of plant biology, soil quality, and biomass collection can be used.
- Structure federal incentives in a manner that provides additional per gallon amounts for cellulosic ethanol, based on the energy efficiency of the production process, including feedstock production; environmental impacts including water and land use; and the resulting carbon emissions. This system should be designed in a manner that encourages innovation by rewarding the development and use of feedstocks and processes with superior lifecycle environmental, energy and emissions profiles.
- Advocate for DOE and U.S. Department of Transportation research, development and demonstrations on vehicle engine technology that more effectively uses biofuels.

State

- Complement federally funded research with state research, development, and demonstrations in delivering appropriate feedstock production and residue removal. Potential resource inventories need to be expanded and evaluated in terms of agricultural science.
- Actively partner with local companies in alternative energy projects, pursuing federal funding where applicable.

3.2.2 Cellulosic and Other Biofuels Feedstock Supply

A study undertaken by University of Tennessee[14] looked at the economic, environmental, and agricultural impacts of increasing levels of ethanol production and use. The results of the study show that further expansion of production (10 billion gallons in 2010, 30 billion gallons in 2020, and 60 billion gallons in 2030) is well within the capability of the industry and farmers under conservative grain-yield improvement assumptions and market entry of modest amounts of cellulosic-derived ethanol production by 2012.

[14] http://www.energyfuturecoalition.org/pubs/UTReport.pdf

Steps are needed to actualize this potential supply of cellulosic feedstocks for Biofuels. Currently there is no functioning market for perennial Biofuels feedstocks. There are uncertainties about the conditions under which these and other energy crops can even grow in the West. The following recommendations will support and encourage the transition to cellulosic feedstocks.

- Provide government assistance to implement short- and medium-term burden sharing for producers. Expand technical assistance from the Natural Resources Conservation Service and the cooperative extension services.
- Consider making funds available to cost-share purchases of new bioenergy harvesting machinery.
- Establish a low-carbon renewable fuels loan guarantee program.
- Re-evaluate the USDA risk management program and adjust, as necessary, to meet the needs of evolving bioenergy crops.
- Consider establishing a regional ethanol reserve to maintain an assured supply.

3.2.3 Increasing the Demand for Biofuels

The ethanol industry now produces approximately 6 billion gallons annually, with an additional 6-10 billion gallons of production under construction or planned to come online over the next 5 years. The following recommendations are a set of state, regional, and federal policies that would work together to increase the demand for biofuels:

<u>National</u>

- Consistent with greenhouse gas reductions and other environmental goals, support implementation of the expanded Renewable Fuels Standard (RFS.)
- Determine market infrastructure needs for distributing biofuels and expand the market capacity to maximize current and projected future consumption patterns.
- Consider the monetization of the cellulosic ethanol trading credit contained in the current RFS.
- Because government fleets are in a position to be movers for alternative fuels, the federal government should promote procurement of flex-fuel vehicles, as well as renewable fuels, and ensure the availability of E85 and other renewable fuels fueling facilities.
- Federal agencies can help establish income streams with long-term cellulosic ethanol supply contracts for federal and state purchases.

<u>State</u>

- Promote procurement of flex-fuel vehicles, as well as renewable fuels, and ensure the availability of E85 and other renewable fuels fueling facilities.
- Help establish income streams with long-term cellulosic ethanol supply contracts for federal and state purchases.
- Consider adoption of a low-carbon fuel standard similar to that adopted by California, which is 10-percent reduction in the carbon intensity of transportation fuels by 2020.
- Consider modifying their highway taxes to address the lower BTU content of E85.

3.2.4 Production and Infrastructure

<u>National</u>

- Tie infrastructure incentives to the increased penetration of alternatively fueled vehicles, i.e. for every one percent increase in flex-fuel vehicles sold, additional dollars will be made available for helping to increase the infrastructure development for that technology.
- Adopt a city-to-region approach to solve the E85 infrastructure challenge by encouraging DOE funding of a high-profile competition providing funds to three metropolitan areas.
- Promote federal and state cooperation in developing and enforcing biodiesel fuel quality and labeling.
- Support long-term low interest loans for biodiesel and renewable diesel infrastructure, refining, oil mill and production agriculture.

State

- Actively partner with local companies in alternative energy projects, pursuing federal funding where applicable, and consider the full gamut of financial incentives to encourage growth of the industry, including appropriate tax incentives and loan guarantees.
- Establish goals for increasing E85 infrastructure and for supporting those goals with tax incentives.
- Adopt incentives for retailers to sell E85.
- Ensure biodiesel uniform labeling and adequate state agency education and funding for fuel quality assurance in production and distribution.

Regional

- Plan for distribution of high-volume alternative fuels and other infrastructure components, including storage, rail and tanker trucks.
- Establish grants for renewable fuel infrastructure corridors in the West that serve all of the renewable and advanced biofuels.

4 Evaluating the Benefits of Bioenergy Development in the Western States

Renewable energy development offers an array of benefits to the nation and the Western United States. At the top of the list, renewable energy resources offer the capability to supply sustainable resources for the long term which can partially replace the consumption of the extensive but ultimately limited fossil energy resource. The concept of sustainability is a term that is rapidly being refined and attempts to quantify it are imperfect but both resource longevity and reduced impact on the environment are key components. Beyond the characteristic of providing a non-depletable resource, renewable energy is also favored for its potential to reduce the flow of Greenhouse Gases (GHG) into the atmosphere while providing energy services – a critical environmental benefit. Biomass can be said to play a unique role in the renewable energy portfolio. When the biomass resources used for energy production are wastes and residues from urban, forest and farm activities that would otherwise require some form of disposal or disposition, the energy alternative also displaces the alternative disposal fate for the residues. This ability to derive economic and environmental benefits from what might otherwise be environmental and economic liabilities is particularly attractive with significant implications for GHG mitigation.

4.1 Converting Biomass Residues and Wastes to Energy

There is a general consensus that within certain constraints the use of biomass residues or wastes to produce energy can have a profound impact on the reduction of GHG flows into the atmosphere. In the baseline scenario 35% of the resources for Biofuels production are derived from residues and waste sources (including forest residues; agricultural residues such as orchard & vineyard waste, corn stover and wheat straws; municipal solid waste; and tallow and waste grease).

At the outset of the study the assessment team considered options for evaluating the net benefits associated with projected deployment scenarios. With limited resources the team pursued an adaptation of the benefits model used for the CDEAC study for Biopower development. That adaptation was partially successful in treating forest and urban residues and wastes as feedstocks but was not sufficiently complete with regard to agricultural feedstocks to report results for that sector. Realizing that the efforts required to complete that assessment definitively go well beyond the scope of this project, only the preliminary findings and qualitative discussion of the issues are included here as part of the evaluation of residue feedstocks. The use of biomass for alternate energy production does avoid the need for alternative disposal of residue feedstocks. While biomass energy production causes environmental impacts during fuels collection, preparation and conversion to energy, these impacts have to be balanced against the avoidance of impacts associated with an equivalent amount of energy generation from fossil fuels and the avoidance of the environmental impacts that would otherwise be caused by conventional or other alternative disposals of the biomass feedstocks converted to fuels. *The latter effect, avoidance of alternative disposal of biomass residues, quantitatively is the largest single source of the environmental benefits per gallon of fuel produced.*[15]

The net environmental impacts of biomass energy production are defined as the impacts of the energy-production and use pathway, less the sum of the impacts of the alternative production and use of the same amount of energy from fossil fuels **plus** the impacts of alternate disposal of the biomass residues converted to fuel. In order to analyze the net

[15] CDEAC 2006, Morris 1999, Morris 2000, Morris 2008

environmental implications of using biomass resources for energy production, it is necessary to determine what the alternative fate of the biomass would be if it were not used for energy production. Avoidance of three alternative fates: open burning, burial in a landfill or open pile, or accumulated as overgrowth in the region's forests have the greatest impact on GHG reduction. Open burning produces as much as 100 times more conventional pollutants than conversion to fuel and controlled combustion of the fuel in an engine, and greater quantities of greenhouse gases due to poor (incomplete) combustion conditions in open burning. Accumulation of forest overgrowth can have negative consequences for fish and wildlife habitat, reduces forest growth and resiliency to natural disturbance regimes (insects, disease, drought and weather events), increases the risk of devastating wildfires, and degrades the functioning of forested watersheds, both with respect to the amount and seasonality of water production, as well as water quality and sediment delivery to domestic water impoundments (Morris 1999, Morris 2000, Morris 2008). By contributing to forest health and fire resiliency in currently at-risk, overstocked forests across the West, in the long term energy production from forest fuels can increase the amount of carbon that is stored on a sustainable basis in the earth's forests, making a positive contribution to efforts to control atmospheric greenhouse gas levels. At the same time best management practices require that some portion of the residues from forests and fields must be left on the land replenish and protect the soil.

Landfill burial of segregated woody biomass, which can be diverted for productive uses such as recycled products or energy production, consumes available landfill space, and produces much greater quantities of greenhouse gas emissions than controlled combustion of the diverted material. However collection and use of landfill gas as a fuel for power production has made significant strides in reducing this environmental burden and is a growing part of the biomass energy portfolio for the West. The energy production pathway provides an environmentally superior beneficial use for the biomass residue that is being converted than any of the alternative disposal options that are available.

There are a wide range of values reported for the emissions and water use for various steps in the field to fuel processes (refer to the accompanying report volumes on biofuel technology conversion and biomass resources for more details). Of the various impact categories considered in the model, the greenhouse gases contribute approximately 80 percent of the total value of the ancillary benefits. This value is calculated using the base-case value of $20 per ton of CO2 equiv. for greenhouse gases. Using the current US value for greenhouse gas emissions of $3 per ton as the lower boundary, and the current EU value for greenhouse gas emissions of $30 per ton as the upper boundary, produces a range of 7 to 30 ¢ per gallon of Biofuel produced for the ancillary benefits of biomass fuels production depending on many factors. For the residues this value is highly dependent upon assumptions about alternative fates discussed above. These are very preliminary findings based on GHG generation factors for each step of the process from field to fuel (well to wheel) compiled from many previous studies.[16] As such the assessment team believes that they are more an indication of the positive trends for the use of residue resources than absolute values that can be taken to the bank (literally in the case of the emerging and growing markets for emissions trading). The WGA recommends that a single consistent platform for benefits analysis that is transparent to all who review the inputs and results will be a cornerstone for properly valuing the net benefits of Biofuels in the West.

[16] Such as Delucchi 2003, Sheehan 1998, Wu 2006. Refer to emissions discussion in Task 1 and Task 2 reports for additional details and sources.

4.2 Land Conversion Impacts of Bioenergy Development on Biogenic Carbon Neutrality and Food Production

The issue recently raised by energy research, policy and environmental organizations is that the Bioenergy carbon accounting analysis should take into account the full impacts of conversion of land to energy crops for Biofuels production.[17] What is the impact of land conversion on food production capability (including feed for livestock) and carbon accounting for biomass energy production? The term carbon accounting or carbon neutrality as used in this report encompasses the carbon equivalents of all significant sources of greenhouse gases contributing to global warming such as emissions of N_20 and CH_4. Bioenergy systems are carbon neutral with respect to the carbon that is embodied in the biomass to the degree that biomass regrowth occurs at a rate that replenishes in the near term the biomass feedstocks used. The biogenic carbon in the biomass is already part of the linked stocks of carbon in the earth's atmosphere and biosphere. However, Bioenergy systems can affect biogenic carbon stocks and flows in ways that can be positive in some cases, and negative in other cases, with respect to their affects on atmospheric greenhouse-gas levels. For example, on the positive side, the use of a variety of biomass-residue resources for energy production reduces the potency of the greenhouse-gas emissions associated with alternative disposal options for the residues, such as open-air decomposition, burial or open burning, by replacing environmental CH_4 emissions with CO_2 emissions. Unlike Bioenergy, fossil-fuel combustion will always add new carbon to the linked stocks of atmospheric and biospheric carbon until carbon capture and sequestration (CCS) systems are proven to be long lasting and economic. By contrast application of CCS to Bioenergy systems can change Bioenergy production and use to a net sink for carbon and that is a very attractive advantage for Bioenergy technologies.

On the negative side, the production of biomass resources can lead to significant losses of fixed biogenic carbon, for example due to the clearing of land in anticipation of establishing a crop, as well as losses of soil-bound carbon due to tillage and other agricultural or silvicultural practices. In addition, biomass resource production can lead to potent greenhouse-gas emissions in the form of N_2O from the use of nitrogen fertilizers. Emissions of biogenic and non-carbon greenhouse gases due to land clearing and subsequent carbon emissions from fossil fueled operations involved in the production of biomass resources are not covered by the carbon-neutral attribute of biomass energy. The rate of regrowth with carbon intake compared to the energy portion of the harvest and carbon emissions from site conversion is the key determinant of carbon neutrality. The portion of the harvest that is converted into forest products continues to sequester the carbon.

When the resource is produced primarily for a non-energy application, such as food or fiber, then it can be argued that GHG emissions can be attributed, in whole or part, to the primary objective of the agricultural enterprise. This appears to be reasonable in cases like the use of residues for energy production, such as corn stover for lignocellulosic ethanol production, as long as sufficient residues are left in the field to sustain corn production. When additional fertilizer must be added to make up for nutrient loss then that must be ascribed to the energy system. In terms of the corn grain itself, which is used for conventional ethanol production and livestock feed, the carbon equivalent emissions should indeed be assigned to

[17] Mitigation of climate change is a policy goal of bioenergy development in many countries. However, life-cycle analyses that measure emissions throughout the bioenergy production chain indicate a wide divergence in carbon balances according to technologies used, locations and production systems - with some even leading to greater emissions than fossil fuels. Food and Agriculture Organization (FAO) of the United Nations, Web Document http://www.fao.org/bioenergy/47285/en/

the energy system, in proportion to the mass of products produced - energy versus food/feed products.

4.3 WGA Strategic Assessment Approach

The WGA analysis suggests that the production of Biofuels from lignocellulosic feedstocks is the future of the industry. Therefore the emphasis in our assessment is on the impacts of using lignocellulosic biomass for large scale future energy production. Nearly half the projected lignocellulosic biomass resource for 2015 is derived from residues from other activities (such as forest thinning, timber milling, corn production). In this case there is no land conversion as the land remains in its current predominant productive use, e.g. food production or timber production. For the cases where energy crops are established, land conversion is a necessary step. The carbon accounting analysis should consider what the carbon emissions and uptake would be in two cases – (1) let the land be preserved in its current use and (2) convert the land to long term Bioenergy production. The complicating factor is projecting the alternative fates or end uses for the standing biomass harvested from the land and converted to Bioenergy crops, while considering current management practices on the land which allow for soil tilth maintenance for example. Conversion materials harvested in site preparation to products or Bioenergy (meeting demands for fiber or displacing fossil fuels) can potentially involve positive outcomes. There are several direct impact scenarios to consider for lignocellulosic Bioenergy development. In each case we indicate under what circumstances the condition of near carbon neutrality is maintained for Bioenergy production. With appropriate policy and regulatory safeguards to assure that these conditions are achieved, a significant portion of the energy needs for the Western states can be satisfied with biomass on a large scale while accruing the environmental and economic benefits associated with Bioenergy.

For each of the many land conversion scenarios we identify the possible products of land conversion and then indicate under what conditions carbon neutrality and food production capacity can be maintained. *For this study we are focused on land conversion practices as they occur in the United States, especially the Western States, and not as they might unfold globally, although these same principals can apply in similar climate and economic conditions.* We expect research will continue in this area to determine more precisely the degree of balance in these outcomes.

Land conversion scenarios with direct impact on carbon neutrality include:

1. Conversion of forest land to Bioenergy crops: this is the reverse of a longstanding trend in the U.S. where former agriculture land has been allowed to revert back to forest land as agriculture has diminished particularly in the eastern U.S. In this case the forest biomass will in most cases be harvested for commercial purposes to capture the value of the existing biomass.
    a. Conversion harvest products include: timber, pulp or fiber chips, mulch, animal bedding and Biofuel feedstock material
    b. Conditions for maintaining carbon neutrality: the conversion harvest produces timber which maintains long term carbon sequestration, pulp which can maintain long term sequestration to the degree that the fiber is recycled, and Biofuels[18] which displace fossil carbon emissions. Land preparation must

[18] This document assumes the future ability for lignocellulosic ethanol conversion processes to be able to accept a wide range of biomass feedstocks. In the case this cannot occur both on site power generation through combustion and landfilling with methane collection for power generation will serve to mitigate the carbon debt from the conversion process.

minimize the disturbance of soil carbon to the extent practical but removal or grinding down the large root systems will likely incur a carbon penalty (20 to 36% of the biogenic carbon can be retained in the root system).
   c. Conditions for protecting food production capacity: Conversion of forest land has no direct impact on food production for humans.
2. Conversion of agriculture working lands (food/feed cropland and pastureland to Bioenergy crops: In the cropland case establishing a new crop should not incur a large deficit since the original biomass was also harvested and replanted for beneficial use without a large aggregation of carbon in long term storage. For pasture land the conversion has minimal direct impacts on the carbon stored above and below ground when no till methods are used.
   a. Conversion harvest products: food and agricultural residues
   b. Conditions for maintaining carbon neutrality: The agricultural residues are converted into Biofuels displacing fossil fuels. Land preparation must minimize the disturbance of soil carbon to the extent practical – best practices may include "no till" field prep, cover crops to reduce herbicides and optimized recovery of nutrients and application of fertilizers.
   c. Conditions for protecting food production capacity: Conversion of marginal cropland to bioenergy cropping scenarios will probably have minimal impact on food production for humans and actually may be better from an environmental/sustainability perspective due to increased carbon sequestration and soil and water quality benefits. Conversion of prime cropland to Bioenergy crops could possibly impact food production capacity, but these may potentially be offset if historic trends in food crop yields continue. To the degree that rate is exceeded, clearly food production will be adversely impacted with significant repercussions.
3. Conversion of Conservation Reserve Program (CRP) land to Bioenergy: This is a special case. Crops like Switchgrass are conservation reserve crops and can maintain the conservation values while being harvested for productive uses. In this case unused biomass now goes to productive energy uses and the benefit is on the positive side of the ledger. Conversion of CRP to corn on the other hand has the opposite effect. The conservation values are lost but the productive energy use remains.
   a. Conversion harvest products: native or hybrid grasses for Biofuels
   b. Conditions for maintaining carbon neutrality: Harvests with adequate residues left to protect and enrich soils should maintain neutrality.
   c. Conditions for protecting food production capacity: Conversion of CRP to energy crops has no direct impact on food production for humans.
4. Clear-cut forest land for energy harvests or development: In the U.S. this situation occurs where landowners have let agricultural lands revert to a forested condition without restocking and the result is largely unmerchantable timber and scrub vegetation. Once clear-cutting is performed the owner has a choice to restock the land or to again allow natural regrowth. When the land is being developed for housing and urban uses then the outcome is permanent conversion and the motivation for the harvest is no longer to produce energy crops.
   a. Conversion harvest products: fiber, mulch, bedding and fuel
   b. Conditions for maintaining carbon neutrality: Harvested biomass converted into fuel, displacing fossil fuels, or to fiber for building products will largely assure neutrality. Land preparation for replanting must minimize the disturbance of soil carbon to the extent practical but removal of the large root systems will incur a carbon penalty.
   c. Conditions for protecting food production capacity: Site conversion of former agricultural lands has already occurred in this instance and maintaining it as

forestland will have no impact on food production capacity. On the contrary if the feedstock harvest allows the land to be reestablished as farm land an increase in food production could occur.

In all these cases a common variable directly impacting carbon neutrality is the energy required to harvest/collect and haul raw feedstock to the Biorefinery. To the degree that fossil inputs are used in this step – low density resources will decrease the net GHG and energy benefits. The spatial modeling done by UCD for this assessment has increased the resolution of the determining the impact of this variable. High yield systems that don't proportionately increase fertilizer use and use for biofueled fleets for harvesting and hauling can alter the equation substantially.

It is interesting to note that society has implicitly accepted the environmental consequences of land conversion and use in order to produce food and fiber crops, although significant efforts have been made on an increasing scale over the past several decades to improve domestic agricultural and forestry practices from an environmental perspective. However for energy crops, recent increases in food prices have been attributed by some analysts to the increasing use of corn for ethanol production in the U.S. Other analysts counter that food prices are responding to a variety of pressures, of which corn use for ethanol production is only one small factor. As this study suggests the fuel versus food equation for ethanol production changes markedly when the feedstocks are the lignocellulosic resources. There will be land-use conflicts and impacts associated with the production of these energy resources quite different from those associated with current biofuel technologies, and they can be minimized via appropriate land use and energy policy and regulation.

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